EECS 373 Midterm 2
Winter 2023

23 March 2023

No calculators, reference material, internet, or communicating with others about the exam (except course staff).

Name

UM Uniqname

Sign below to acknowledge the Engineering Honor Code: "I have neither given nor received aid on this examination, nor have I concealed a violation of the Honor Code."

Signature

The number of points per problem are not well correlated to the time required. This is intentional, as we want students with good basic knowledge to get reasonably high scores, but for students with deeper understanding to receive higher scores.

1 Datasheets (10 pts.)

You are designing an embedded system containing a Freescale Semiconductor MPC885 microcontroller. In your application, it will need to run at 133 MHz 10% of the time, 80 MHz 10% of the time, and 66 MHz the rest of the time. Assume that I/O power consumption is negligible. What is the average current required by the processor in your application? Please see the following datasheet for information about the part. The right margin may be used to show work.

◯ 181 mW. ◯ 326 mW. ◯ 181 mA. ◯ 326 mA. ◯ 224 mA.

Answer: 181 mA.

5 Power Dissipation

Table 5 provides information on power dissipation. The modes are 1:1, where CPU and bus speeds are equal, and 2:1, where CPU frequency is twice bus speed.

Table 5. Power Dissipation (P_D)

Die Revision	Bus Mode	CPU Frequency	Typical[1]	Maximum[2]	Unit
0	1:1	66 MHz	310	390	mW
		80 MHz	350	430	mW
	2:1	133 MHz	430	495	mW

1 Typical power dissipation at $V_{DDL} = V_{DDSYN}$ = 1.8 V, and V_{DDH} is at 3.3 V.
2 Maximum power dissipation at $V_{DDL} = V_{DDSYN}$ = 1.9 V, and V_{DDH} is at 3.5 V.

NOTE

The values in Table 5 represent V_{DDL}-based power dissipation and do not include I/O power dissipation over V_{DDH}. I/O power dissipation varies widely by application due to buffer current, depending on external circuitry.

The V_{DDSYN} power dissipation is negligible.

6 DC Characteristics

Table 6 provides the DC electrical characteristics for the MPC885/MPC880.

Table 6. DC Electrical Specifications

Characteristic	Symbol	Min	Max	Unit
Operating voltage	V_{DDL} (core)	1.7	1.9	V
	V_{DDH} (I/O)	3.135	3.465	V
	V_{DDSYN}[1]	1.7	1.9	V
	Difference between V_{DDL} and V_{DDSYN}	—	100	mV
Input high voltage (all inputs except EXTAL and EXTCLK)[2]	V_{IH}	2.0	3.465	V
Input low voltage[3]	V_{IL}	GND	0.8	V
EXTAL, EXTCLK input high voltage	V_{IHC}	0.7*(V_{DDH})	V_{DDH}	V
Input leakage current, Vin = 5.5 V (except TMS, $\overline{TRST}$, DSCK and DSDI pins) for 5-V tolerant pins [2]	I_{in}	—	100	µA
Input leakage current, $V_{in} = V_{DDH}$ (except TMS, $\overline{TRST}$, DSCK, and DSDI)	I_{In}	—	10	µA
Input leakage current, V_{in} = 0 V (except TMS, $\overline{TRST}$, DSCK and DSDI pins)	I_{In}	—	10	µA
Input capacitance[4]	C_{in}	—	20	pF

2 Prototyping (5 pts.)

Which two are least likely to help during (de-)soldering?

○ 

○ 
○ 

○ 
○ 
○ 

Answer: There was no need to know what the useless items were. Identifying the four useful items was sufficient for a correct answer. The useless ones were Finnish licorice and a magnetic aquarium glass cleaner. The useful items were a pencil eraser for cleaning thin corrosion layers and other solder-resistant material from copper before soldering, sal ammoniac for tinning the soldering iron, a soldering sponge for tinning, and a solderpult for removing solder.

3 Power consumption, temperature, and reliability (15 pts.)

1. Indicate the equation for switching power consumption. (5 pts.)
   - ○ $C \cdot V_{DD} \cdot f \cdot A$
   - ○ $C \cdot V_{DD}^2 \cdot f \cdot A$
   - ○ $b/8 \cdot (V_{DD} - 2 \cdot VT)^3 \cdot f \cdot A \cdot t$
   - ○ $A_S W/L \left(1 - e^{-V_{DS}/q}\right)$
   - ○ $b/12 \cdot (V_{DD} - 2 \cdot VT)^3 \cdot f \cdot A \cdot t$

   Answer: $C \cdot V_{DD}^2 \cdot f \cdot A$**.**

2. If one halves the clock frequency of a DVFS-capable microcontroller in which power consumption is dominated by switching power, thereby doubling the time to complete a task, what happens to its power consumption. (5 pts.)
   - ○ It stays the same.
   - ○ It drops to roughly one half.
   - ○ It doubles.
   - ○ It drops to 1/4.

   Answer: It drops to roughly one half.

3. If one halves the clock frequency of a DVFS-capable microcontroller in which power consumption is dominated by leakage power, thereby doubling the time to complete a task, what happens to its power consumption. (5 pts.)
   - ○ It stays the same.
   - ○ It drops to roughly one half.
   - ○ It doubles.
   - ○ It drops to 1/4.

   Answer: It stays the same.

4 Motors (4 pts.)

What is a motor brush?

- ◯ Conductive blocks that electrically connect rotor and stator.
- ◯ Motor cleaning tool.
- ◯ Electronic beard grooming device.
- ◯ Metal shavings that build up in the rotor, eventually shorting its coils.
- ◯ Finnish licorice brand.

Answer: Conductive blocks that electrically connect rotor and stator.

5 Power Regulation (10 pts.)

1. How efficient are typical, properly used switching voltage regulators? (5 pts.)

   ◯ 2%. ◯ 15%. ◯ 50%. ◯ 85%. ◯ 97%.

   Answer: 85%.

2. When using a transformer for AC–DC conversion, which of the following statements is most accurate? (5 pts.)

   - ◯ No filter is needed.
   - ◯ A high-pass filter is needed after the transformer.
   - ◯ A low-pass filter is needed after the transformer.
   - ◯ A high-pass filter is needed before the transformer.
   - ◯ A low-pass filter is needed before the transformer.

   Answer: A low-pass filter is needed after the transformer.

6 Memory (10 pts.)

Indicate whether the following statements are true or false.

1. Several security researchers have exploited the temperature dependence of leakage current by cooling SRAMs with volatile liquids to enable readout after disconnecting them from their power supplies. (2 pts.)

   ◯ False ◯ True

   Answer: False. This is reasonable for DRAMs, not SRAMs.

2. Erasing an EEPROM requires that it be exposed to intense UV light through a quartz window. (2 pts.)

   ◯ False ◯ True

   Answer: False. This works for EPROMS, not EEPROMS, which have no windows.

3. Erasing a FLASH memory device is much faster than reading it because erasure relies on Fowler-Nordheim tunneling. (2 pts.)

   ◯ False ◯ True

   Answer: False. It's slower than reading.

4. From the process technology perspective, SRAM is straight-forward to integrate on the same die as a microcontroller. (2 pts.)

   ◯ False ◯ True

   Answer: True.

5. A single SRAM bit-cell will typically be destroyed by wear after 100,000 writes. (2 pts.)

   ◯ False ◯ True

   Answer: False. SRAM writes don't cause much wear.

7 PCBs (10 pts.)

1. Indicate whether the following statement is true: a PCB for which instantaneous current demands of one or more components cannot be met by the power distribution network in the steady state is invalid because component voltages will droop below the required levels. (5 pts.) ◯ False ◯ True

   Answer: False. Decoupling capacitance can enable reliable operation provided that the instantaneous current demands are brief.

2. Which two of the following approaches are typically used to increase the capacity of a power distribution network to meet momentarily high current demands? (5 pts.)

   ◯ Increasing parasitic inductance.
   ◯ Adding decoupling capacitors.
   ◯ Making traces wider.
   ◯ Liquid cooling.
   ◯ Clock throttling.
   ◯ Increasing parasitic resistance.

   Answer: "Adding decoupling capacitors" and "Making traces wider".

8 Serial Communication (14 pts.)

1. Which of the following protocols support multiple leader (master) devices? Select all that apply. (2 pts.)

   ◯ I2C. ◯ SPI.

   Answer: I2C.

2. Which of the following protocols support multiple follower (slave) devices? Select all that apply. (2 pts.)

   ◯ I2C. ◯ SPI.

   Answer: I2C and SPI.

3. Which of the following protocols are clocked protocols (has a clock signal)? Select all that apply. (2 pts.)

   ◯ UART. ◯ I2C. ◯ SPI.

   Answer: I2C and SPI.

4. Which of the following protocols uses a parity bit for error checking? Select one. (2 pts.)

   ◯ UART. ◯ I2C. ◯ SPI.

   Answer: UART.

5. An engineer is designing an embedded system with one leader (master) device that needs to both read and write to nine other follower (slave) devices. The engineer may use a maximum of 5 wires, in addition to GND and PWR.

   Which one of the following communication technologies may the engineer use? (3 pts.)

   ◯ UART. ◯ I2C. ◯ SPI.

   Answer: I2C.

6. How many wires (not counting GND and PWR) are needed? (3 pts.)

   Answer: 2 wires: 1 for SCL, 1 for SDA.

9 Timers (10 pts.)

You have just started as an intern at EECS 373 Servos Inc. Your first task is to set up an embedded system to press a button by moving a servo between 0 and 90 degrees as described in the following datasheet. You are given the following material: one MG90S Servo & Datasheet and one STM32W373 Nucleo (see the next page).

Another intern has already done the wiring for you. Your job is to set up one of the timers to control the servo using PWM. The STM32W373 Nucleo has the following timer: TIM 1: 100 kHz clock, 8 bit ARR, and 8 bit CCR.

Find appropriate values for the ARR, Prescaler, and CCR. You can assume all registers count up. Show your work below.

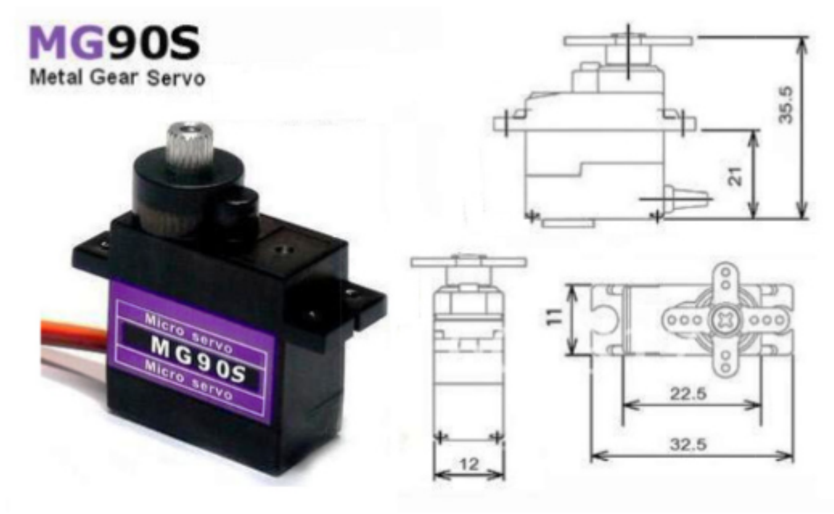
1. ARR Value (3 pts.)

2. Prescaler Value (3 pts.)

3. CCR Value [0 deg] (2 pts.)

4. CCR Value [90 deg] (2 pts.)

   Answer: ARR < 256 and CCR < 256
   (1 / (100,000/Prescaler)) * ARR = 20 / 1000
   For Part 3, CCR/ARR = 1.5/20
   For Part 4, CCR/ARR = 2.0/20
   Using the above equations, students are given full credit for solutions ARR_ALT and Prescaler_ALT where ARR_ALT = ARR - 1 and Prescaler_ALT = Prescaler - 1.
   Example Solution:
   ARR = 200, Prescaler = 10, CCR = 15, and CCR=20.



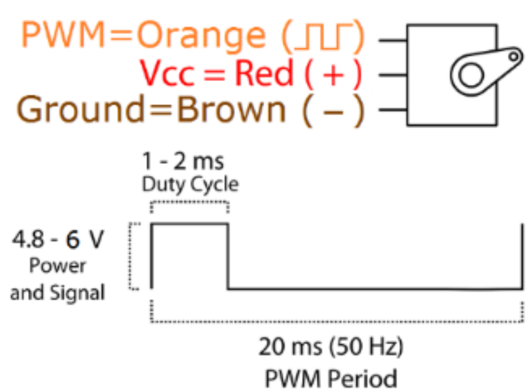
MG90S servo, Metal gear with one bearing

Tiny and lightweight with high output power, this tiny servo is perfect for RC Airplane, Helicopter, Quadcopter or Robot. This servo has *metal gears* for added strength and durability.

Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but *smaller*. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.

Specifications

- Weight: 13.4 g
- Dimension: 22.5 x 12 x 35.5 mm approx.
- Stall torque: 1.8 kgf·cm (4.8V), 2.2 kgf·cm (6 V)
- Operating speed: 0.1 s/60 degree (4.8 V), 0.08 s/60 degree (6 V)
- Operating voltage: 4.8 V - 6.0 V
- Dead band width: 5 µs



Position "0" (1.5 ms pulse) is middle, "90" (~2 ms pulse) is all the way to the right, "-90" (~1 ms pulse) is all the way to the left.

10 Sampling, ADCs, DACs (12 pts.)

1. Given

   - A temperature sensor with a range of -100°C to 400°C, outputting an analog signal ranging from 0 V to 5 V and linearly related to the temperature and
   - A 12-bit ADC with a 0 V–5 V range. The ADC is 1/2 LSB compensated,

   determine the maximum quantization error of the ADC (in volts)? (4 pts.)

   Answer: $(5\,\mathrm{V} - 0\,\mathrm{V})/(2^{12} * 2) = 5\,\mathrm{V}/(2^{13})$.

2. What temperature corresponds with the ADC output value of 5? Disregard quantization error. An unsimplified expression with numbers is fine. (4 pts.)

   Answer:

$$\begin{aligned} V_{in} &= N_{adc} * (\mathit{Vref}+ - \mathit{Vref}-)/2^n + \mathit{Vref}- && (1)\\ \mathit{Temp} &= V_{in} * (500°\mathbf{C}/5\,\mathrm{V}) - 100°\mathbf{C} && (2)\\ &= (5 * 5\,\mathrm{V}/(2^{12})) * 100–100 && (3)\\ &= (2500/2^{12})–100 && (4) \end{aligned}$$

   Alternative Approach

$$\begin{aligned} V &= (1\,\mathrm{V}/100°\mathbf{C}) * (T - (-100°\mathbf{C})) = (1\,\mathrm{V}/100°\mathbf{C}) * (T + 100°\mathbf{C}) && (5)\\ V &= (1/100)T + 1 && (6)\\ \mathit{Temp} &= 100 * (V - 1) && (7)\\ V_{ADC,in} &= ADC_V AL * LSB = 5 * 5/(2^{12}) && (8)\\ \mathit{Temp} &= 100 * (25/(2^{12})–1) && (9) \end{aligned}$$

   We didn't deduct points if the ADC bits were adjusted by one $(2^n–1)$**.**

3. What value will the ADC output (in decimal) when the temperature sensor measures 0°C? Please give a numerical value. (4 pts.)

   Answer: Voltage output by the temperature sensor: $(0°\mathbf{C}–(-100°\mathbf{C})) * (1\,\mathrm{V}/100°\mathbf{C}) = 1\,\mathrm{V}$**.**

$$\begin{aligned} N_{adc} &= (\mathit{Vin}–\mathit{Vref}-) * 2^n * 1/(\mathit{Vref}+ - \mathit{Vref}-) = 1\,\mathrm{V} * 2^{12} * 1/5\,\mathrm{V} && (10)\\ &= \mathbf{round}(819.2)\ \textbf{(ADC value is an integer)} && (11)\\ &= 819 && (12) \end{aligned}$$

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